Editorial
Public Transit Planning and Operation in the Era of Automation, Electrification, and Personalization

THE advent of Connected and Autonomous Vehicles (CAVs) and Mobile Internet technologies is reshaping the public transport sector. Autonomous buses are equipped with varying advanced sensors, and hold great promises to enhancing the responsiveness and flexibility of public transit system. In the context of CAVs, transit operators can not only optimize service headway but also adjust bus capacity to meet the time-varying passenger demand. Anticipated benefits of introducing autonomous buses to the existing transit systems include safety improvement, driver cost reduction, and optimal routing. Bus electrification is another global trend to replace traditional diesel buses for energy savings. Electric buses are advantageous to both operators and passengers due to low greenhouse gas emission, maintenance cost, as well as noise pollution. In recent years, demand responsive public transport (DRPT) services (e.g. customized bus, microtransit) receive huge success thanks to the development of Mobile Internet. Unlike traditional bus services or the fixed-route transit service that relies on passive recipients, fixed stops, and schedules, DRPT can provide personalized service for specific clients through interactive information platform (Internet or smartphone). The aforementioned new types of public transit services significantly improve service quality, reduce energy consumption, and ultimately attract more ridership. To fully explore the benefits of personalized, electric and autonomous transit systems, new analytical models and data-driven methods for transit planning and operation are needed. The authors have selected 15 articles for review in this special issue. A summary of these articles is outlined below.

The article entitled "Automatic feature engineering for bus passenger flow prediction based on modular convolutional neural network" by Liu *et al.* explores how to use Deep Neural Network (DNN) to solve the large-scale bus passenger flow prediction problem. Currently, most existing methods designed for the passenger flow prediction problem are based on a single view, which is insufficient to capture the dynamics in passenger flow fluctuation. Thus, the authors analyze the passenger flow from scopes on both macroscopic and microscopic levels, in order to take full advantage of the information from a variety of views. To better understand the role of different views, decision-tree-based models are used in modeling passenger flow. The defects and key features of decision-tree-based models are then analyzed. The results of the analysis can assist the architecture design of the deep learning network. Inspired by the feature engineering of decision-tree-based models, a modular convolutional neural network is designed, which contains automatic feature extraction block, feature importance block, fully-connected block, and data fusion block.

In the article entitled "A multi-objective robust optimization model for customized bus routes" by Ma *et al.*, the authors propose a multi-objective robust optimization model for customized bus routes. A three-stage hybrid coding method based on NSGA-II algorithm is developed to deal with customized bus route optimization under uncertain conditions. Compared with the hybrid algorithm based on K-means and multi-objective genetic algorithm, this method reveals not only better solution results, but saves 42.11% of computing time. The results are of great value for exploring customized bus route optimization methods and improving the efficiency of customized bus operations.

The article entitled "On the role of battery capacity fading mechanism in the lifecycle cost of electric bus fleet" by Zhang *et al.* develops a transit management framework with full consideration on battery capacity loss to ensure the cost-effective operation of electric bus fleet in the long run. In this framework, the state of battery charge is constrained within a predefined range and the corresponding cost-effective feature is quantified through lifecycle cost analysis. The results show considerable cost saving if the state of battery charge is kept within a range that is as narrow as possible and at a low level, mainly contributed by the substantial extension of battery life. Meanwhile, a number of managerial insights stemmed from the numerical case study are outlined, which can serve as a reference for transit operators to make sustainable management strategy for upcoming era of electric buses.

Urban customized bus companies are increasingly motivated by design efforts that entail more efficient route scenarios to incorporate adaptation to temporal and spatial heterogeneity in travel demand. However, such motivations are usually hindered by ubiquitous arrival unpunctuality resulting from traffic congestion. To resolve this problem, in the article entitled "Time-dependent urban customized bus routing with path flexibility," Guo *et al.* suggest a time-dependent bus route planning methodology that explicitly considers path flexibility between nodes to be visited. A mixed-integer programming model is formulated, where decision-making considerations in bus route planning, path choice between nodes, and passenger assignment are concurrently integrated. A hybrid metaheuristic is proposed to solve the model. The problem and methodology

Digital Object Identifier 10.1109/TITS.2021.3064090

are addressed in a city-scale instance, where the effects of time-window features and traffic congestion, as well as the benefits from path flexibility are investigated.

The article entitled "Suburban demand responsive transit service with rental vehicles" by Zhang *et al.* studies the suburban demand responsive transit service, in which the rental vehicles are introduced to meet the fluctuated demands. The investigated problem with two types of vehicle routes is modeled with a mixed integer linear programming formulation. A branch-and-price algorithm which is composited with two pricing subproblem is built, and the trip sequence constraints are introduced in the master problem to ensure that there is no overlap between the consecutive trips. The efficiency of the proposed algorithm is tested on the benchmark instances and a real-world application, and some managerial insights are devised.

The article entitled "A proactive real-time control strategy based on data-driven transit demand prediction" by Wang *et al.* proposes a proactive real-time control method based on data-driven transit demand prediction. A proactive control strategy is to predict the possible disturbance in the future and takes measures in advance to prevent the disturbance from disrupting the service regularity. Firstly, the further service reliability is assessed based on the evolution of the latest service reliabilities, to justify whether to conduct control actions. Secondly, if a control action is required, predict the transit demand and the number of alighting passengers. Thirdly, according to the predicted results, the bus dispatching time is optimized by minimizing passenger waiting time. A calculation process is introduced to solve the problem and the effectiveness of the proposed method is evaluated with the data of a real transit route.

The article entitled "A data-driven timetable optimization of urban bus line based on multi-objective genetic algorithm" by Tang *et al.* proposes a timetable optimization method based on small-scale data analysis of real bus trajectory. Time-dependent travel time function, bus dwell time estimation and passenger demand calculation are considered to establish a bi-objective programming model. A NSGA-II algorithm with a special encoding and decoding scheme is developed to generate efficient solutions. The experimental results of one real bus route indicate that the proposed method could quickly provide high-quality and reasonable timetable schemes for the administrator in urban transit system.

The article entitled "Multi-modal combined route choice modeling in the MaaS Age considering generalized path overlapping problem" by Li *et al.* proposes a combined route choice modeling problem in the context of multi-modal network. When modeling the multi-modal combined route choices, the random utilities of alternative routes are correlated not only because of the overlapping of physical links, but also because of the overlapping of travel modes. The authors define this problem as the generalized path overlapping problem. To address the generalized overlapping problem, a multi-modal logit kernel (MLK) model is proposed to explicitly consider the correlations of unobserved utilities of combined routes.

The paper entitled "A Novel Model for Designing a Demand-Responsive Connector (DRC) Transit System With Consideration of Users' Preferred Time Windows" by Xin Li, Tianqi Wang, Weihan Xu, and Jia Hu presents a mathematical model to design a demand- responsive connector (DRC) bus operational network for improving the service quality and accessibility of public transportation systems. The proposed model features an integrated framework that simultaneously guides passengers to reach their nearest bus stops and routes buses to transport passengers at selected bus stops to connected stations of major transit systems. Passengers; preferred time for pick up is fully considered in the model. For this purpose, this study proposes a multi-objective mixed-integer linear programing model to effectively capture the interactions between users with their predefined service time windows and DRC bus network. This study further develops a three-stage heuristic to yield suboptimal solutions to the model in a reasonable time. Case study results demonstrate the effectiveness of the proposed model.

The paper entitled "Optimal Routing Design of Feeder Transit With Stop Selection Using Aggregated Cell Phone Data and Open Source GIS Tool" by Ming Wei, Tao Liu and Bo Sun developed a novel bilevel programming model for designing feeder bus routes to simultaneously consider bus stop selection, bus routing, and passenger route/trip choice behavior. The objective of the upper-level model is to minimize the total in- vehicle travel time of passengers. The objective of the lower-level model is to determine bus stop locations and assign passenger demand to stops by minimizing the total passenger walking time. An ant colony optimization-based two-stage heuristic algorithm is developed to solve the bilevel programming model within an acceptance computation time. Different from conventional methods, the proposed methodology benefits from using real temporal and spatial characteristic datasets of travel demand aggregated from cellular data and traveling time and distance matrices under actual traffic conditions resulted from an open geographic information system (GIS) tool. Results of a real-life case study in Chongqing municipality, China, show that the proposed methodology could achieve a significant reduction of 2.9% total passenger travel time compared with a traditional method.

The paper entitled "Joint Optimal Scheduling for Mixed Bus Fleet Under Micro Driving Conditions" by Tianwei Lu and Enjian Yao proposed a joint optimal scheduling method for different fuel-type buses under micro driving conditions. The first feature is to estimate the energy consumption of bus scheduling using the micro energy consumption model of EB and FB. The second feature is to propose a trip time estimation method in the bus scheduling process, considering real- time micro driving conditions. The third and most important feature is to build a joint optimization model for EB and FB scheduling, which covers the trip time estimation method and energy estimation method mentioned above. A heuristic algorithm based on the genetic algorithm is designed to solve this model. The above-proposed approaches are examined based on data from Beijing Public Transport, China.

The paper entitled "Optimal Design for Demand Responsive Connector Service Considering Elastic Demand" by Hongtai Yang, Zhaolin Zhang, Wenbo Fan and Feng Xiao explicitly introduced an elastic demand function embedded with a time deviation penalty model. Based on that, one-vehicle and two- vehicle DRC models are formulated to maximize the social welfare. The decision variables include fare, service area, and operating cycle time. Augmented Lagrange Multiplier Method is applied to solve the optimization problem. Both simulation and numerical studies are performed to verify the validity of the models.

The paper entitled "Bi-objective Optimization for Battery Electric Bus Deployment Considering Cost and Environmental Equity" by Yirong Zhou, Xiaoyue Liu, Ran Wei and Aaron Golub presented a bi-objective optimization model for BEB deployment to consider constraints unique to the BEB system and to address the trade-off between environmental equity for the disadvantaged population and capital investment. The model is further demonstrated using the transit system operated by the Utah Transit Authority (UTA) to offer insights on the benefits gained as a result of BEB deployment. Optimal deployment plans under different budgets are provided to illustrate the effectiveness of the model. The trade-offs in each of the plans are further discussed and compared. This research set the foundation for transit agencies to develop optimal deployment strategies for BEB systems when multiple goals need to be considered, allowing planners and decision-makers to create a transportation ecosystem that better serves livable and sustainable communities.

The paper entitled "Joint Optimization of Running Route and Scheduling for the Mixed Demand Responsive Feeder Transit with Time-dependent Travel mixed demand (i.e., reservation and real-time demands) of the time-dependent road network. A two-stage optimization method was designed together with considering the mixed demands. In this model, the minimum total system cost was used, which is composed of the vehicle running costs and passengers' traveling time costs with constraints including vehicle capacity, passengers' time window, and vehicle running time. A solving algorithm based on the adaptive genetic algorithm was designed by considering the characteristics of the joint optimization model.

The paper entitled "Predicting bus passenger flow and prioritizing influential factors using multi-source data: Scaled stacking gradient boosting decision trees" by Weitiao Wu, Yisong Xia and Wenzhou Jin proposed a novel scaled stacking gradient boosting decision tree (SS-GBDT) model to predict bus passenger flow with multi-source datasets. SS-GBDT includes two modules: the prior feature-generation module and the subsequent GBDT-prediction module. A scaled stacking method is devised by introducing a quasi-attention based mechanism (precision-based scaling and time-based scaling). Taking the newly generated features as input, the prediction module forecasts the passenger flow using GBDT model with stacked data, thereby enhancing the prediction performance. The proposed model is tested in two real-life bus lines in Guangzhou, China. Results show that SS-GBDT not only presents superiority in both prediction accuracy and stability, but can also better handle the multicollinearity issue with multi-source data.

The guest editors would like to express their deep gratitude to all the authors who have submitted their valuable contributions and to the numerous and highly qualified anonymous reviewers. The selected contributions, which represent the current state-of-the-art in the field, will be of great interest to the community. The authors would like to thank the IEEE publication staff members for their continuous support and dedication. Additionally, the authors particularly appreciate the tireless support from Prof. Azim Eskandarian, the Editor-in-Chief of IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS.

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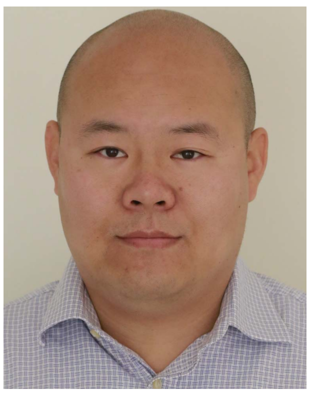

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